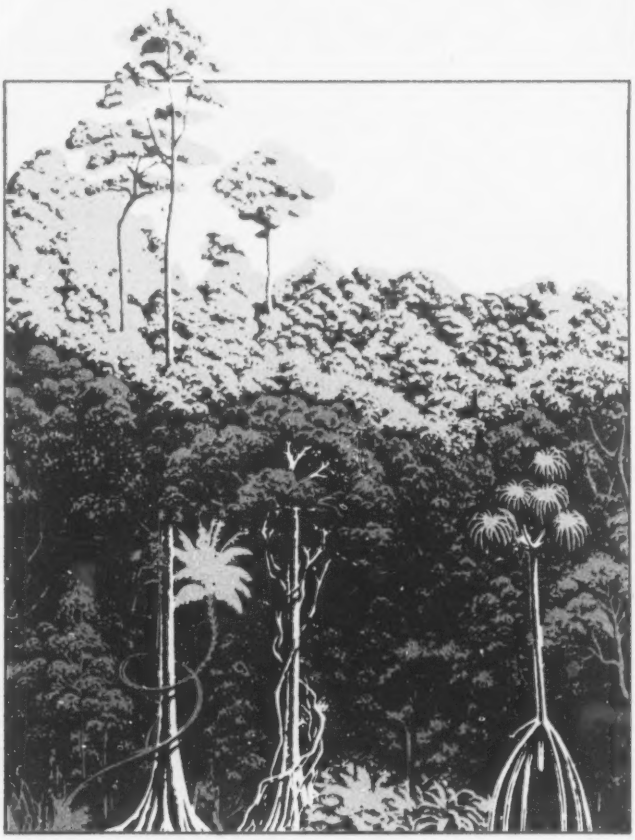
TECHNOLOGIES TO SUSTAIN TROPICAL FOREST RESOURCES

SUMMARY



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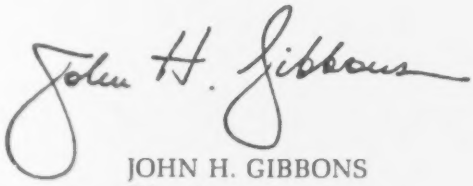
Foreword

The United States has a stake in the sustained economic development of tropical nations for humanitarian, political, and economic reasons. To a great extent, the development of these nations depends on increasing production from their potentially renewable soil, forest, and water resources. But tropical forest resources, which cover nearly one-half of the tropical nations' land, are being consumed at a rate that may make them nonrenewable. They are exploited for timber and cleared for pasture and cropland with little regard for their abilities to produce—in a long-term sustainable fashion—important goods, maintain soil productivity, regulate water regimes, or regenerate themselves.

International recognition of the importance of tropical forest resources, and efforts to sustain the productivity of these resources, have increased significantly in the last decade. In 1980, the House of Representatives, Committee on Foreign Affairs, Subcommittee on International Organizations, held hearings on tropical deforestation. The committee then requested the Office of Technology Assessment (OTA) to conduct a more thorough assessment of the problem, the technologies that could help sustain tropical forest resources, and possible options for Congress. The Subcommittee on Insular Affairs of the House Committee on Interior and Insular Affairs and the Subcommittee on Environmental Pollution of the Senate Committee on Environment and Public Works endorsed the request. The Senate Committee on Energy and Natural Resources asked that the assessment specifically address forest resources of the U.S. insular territories in the Caribbean and western Pacific.

This summary presents the study's major findings. The full report and its two background papers (*Reforestation of Degraded Lands*, and *U.S. and International Institutions*) identify and discuss in-depth some of the constraints and opportunities to develop and implement forest-sustaining technologies.

OTA greatly appreciates the contributions of the advisory panel and workshop participants assembled for the study, the authors of the commissioned technical papers, and the many others who assisted us, including liaisons from other Government agencies. As with all OTA studies, however, the content of the report is the sole responsibility of the Office.



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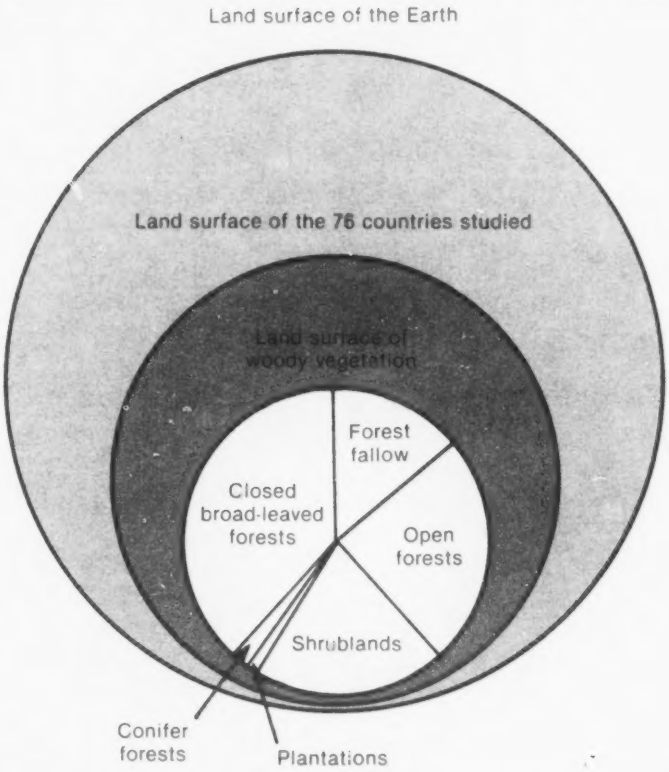
Technologies to Sustain Tropical Forest Resources

INTRODUCTION

Forests of various kinds cover 42 percent of the tropical nations' land (fig. 1). To support a population of 2 billion, these nations must use the natural resources found in these forests: soil, water, plants, and animals. The productivity of these resources can be renewable, but only if tropical people use resource-sustaining technologies.

Some tropical nations are experiencing severe shortages of forest products and services. To avoid even more acute problems, they need to restore resource productivity. Other nations, even those with ade-

Figure 1.—Global Areas of Tropical Woody Vegetation



SOURCE: M. Hadley and J. P. Lanley, "Tropical Forest Ecosystems: Identifying Differences, Seeking Similarities," *Nature and Resources* UNESCO, 19(1):2-19, 1983.

quate forests, need to sustain their forest resources to avoid future problems. In just 30 years, the population of tropical nations is expected to double to 4 billion people. Thus, the importance of tropical forest productivity is increasing as more and more people depend on forest products and services for basic needs such as fuel, materials for shelter, and a reliable water supply.

Substantial institutional activity is occurring worldwide that directly or indirectly benefits tropical forest resources. The U.S. Agency for International Development (AID), the United Nations agencies, the multilateral development banks, and others have increased their attention to forestry in recent years. Private corporations and nonprofit organizations also have been involved in the search for solutions to tropical forest problems. Most importantly, tropical nations' governments have come to recognize that deforestation and forest resource degradation constrain their economies and their development options.

The large number of organizations that have some responsibilities in forestry might imply that an adequate level of activity is under way. But the total amount of expertise and funding available to forestry still remains small relative to the scope of the problem. International development assistance organizations cannot fund enough forest conservation to offset deforestation because the underlying institutional causes can only be resolved by the tropical countries themselves.

IMPORTANCE OF TROPICAL FOREST RESOURCES

For tropical nations, forests and shrublands provide wood for lumber and paper, building materials, and fuel, and are an important source of foreign exchange. Forests help maintain soil quality, limit erosion, stabilize hillsides, modulate seasonal flooding, and protect waterways and marine resources from accelerated siltation. In addition, many millions of people living in and near the forests depend directly on them for food, medicines, and other basic needs.

The benefits from tropical forests are not limited to tropical nations. World trade in tropical wood is significant to the economies of both the producing and consuming nations. The United States is the second largest importer of tropical wood products, and U.S. demand for tropical wood has been growing at rates well above our population and gross national product growth rates. Tropical forests also provide a broad array of nonwood products such as oils, spices, and rattan that are valuable for both subsistence and commerce. The annual world trade in rattan, for example, is estimated to be $1.2 billion. Thus, industrial wood and other forest product exports earn substantial foreign exchange for nations that trade with the United States.

The productivity of renewable resources in the Tropics affects both the economic viability of U.S. investments overseas and political stability in the tropical nations. Many development projects funded by the U.S. Government or the U.S. private sector are being undercut by flood-

ing, siltation of reservoirs, pest outbreaks, and other problems associated with deforestation. Food and jobs, both critical for political stability in developing nations, can be reduced by the consequences of deforestation.

The highly diverse tropical forests contain plants, animals, genetic material, and chemicals that have great potential value for medicine, agriculture, and other industries. The Tropics are thought to contain two-thirds of the world's approximately 4.5 million plant and animal species. An estimated 2.5 million of the tropical species are yet unknown to science. Considering the value to society that has come from those tropical species that have been studied (e.g., many major agricultural crops, anticancer drugs, insects used in integrated pest management), it is very likely that some of the remaining unstudied species offer potentially important resources, particularly for pest control, plant breeding, genetic engineering, and other biotechnologies. Biologists are already using new techniques for cloning plants and micro-organisms to screen existing organisms for their production of useful chemicals.

Tropical forests also provide habitats for many of the world's migratory birds and various endangered species. About two-thirds of the birds that breed in North America migrate to Latin America or the Caribbean for winter. Some of these migratory birds play an important role in controlling agricultural pests in the United States.

STATUS OF TROPICAL FORESTS

Some 76 nations located entirely or largely within the tropical latitudes contain about half the world's population (approximately 2 billion). These nations are characterized by rapidly growing populations, low per capita incomes, and predominantly agrarian economies. Near forest lands, much of the agriculture is subsistence farming, often in upland areas where soils are dry or have low fertility. Commercial agriculture, on the other hand, generally is sited on the more fertile and often irrigated alluvial plains of major river valleys. Both types of agriculture are strongly affected by the 1.2 billion hectares* of moist tropical forest and 800 million hectares of drier open woodlands.

The type and distribution of forests vary considerably across regions in the Tropics (fig. 2). Two-thirds of the closed forests** are found in tropical America, while Africa has two-thirds of the open forests.*** Even within regions, forest types are unequally distributed among countries.

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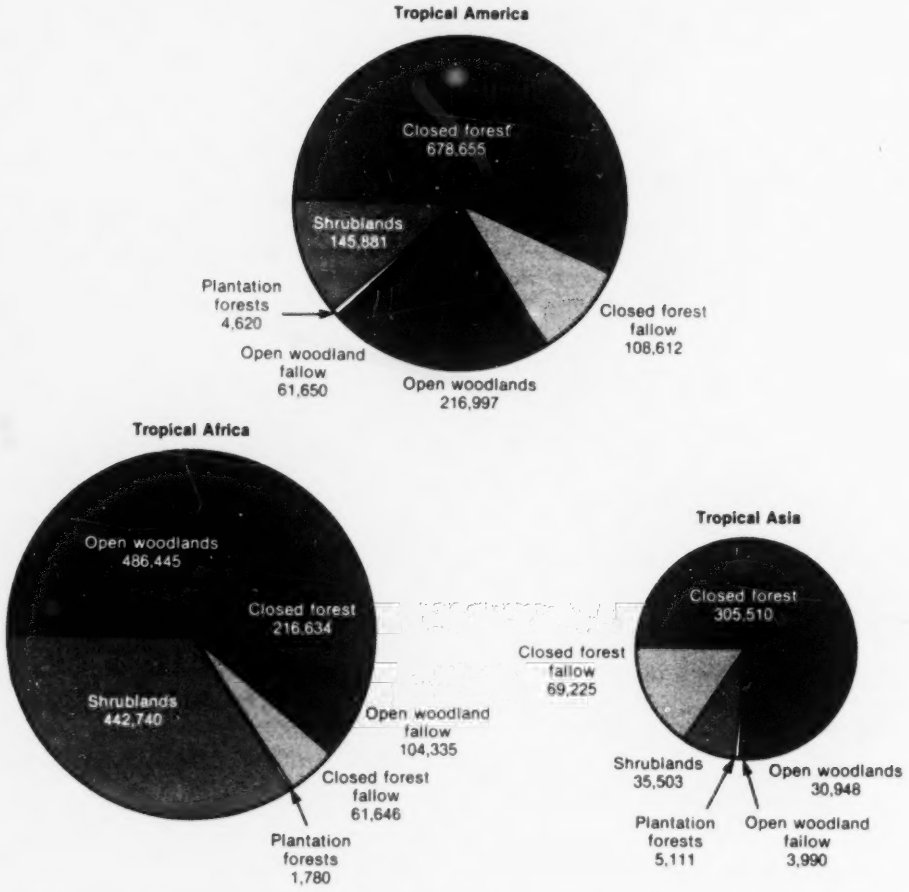
*One hectare equals 2.47 acres.

**Closed forest means that trees shade so much of the ground that a continuous layer of grass cannot grow.

***Open forest has trees that cover at least 10 percent of the ground but still allow enough light to reach the forest floor so that a dense, continuous cover of grass can grow.

Figure 2.—Areas of Woody Vegetation[a] in 76 Tropical Nations
(thousands of hectares, 1980 estimates)



[a]Closed forest has dense tree canopies and no continuous grass cover. Open forest has scattered trees and continuous grass cover. Forest fallow is land used for or abandoned from agriculture. Shrubland has woody vegetation under 7 meters high.

SOURCE: Office of Technology Assessment.

Data on the extent and condition of tropical forests are widely scattered and often inaccurate. Overall figures for deforestation* mask considerable differences among the rates at which individual countries are using and altering their forest resources (table 1). If present trends were to continue, nine tropical countries would eliminate practically all of their closed forests within the next 30 years and another 13 countries would exhaust theirs within 55 years.

Estimates of overall deforestation rates also conceal significant differences in the types of tropical forest affected. The loss of species is probably greatest in the broad-leaved humid lowland forests as these

*Deforestation is the conversion of closed or open forest to nonforest. A distinction should be made between deforestation and degradation; the latter refers to biological, physical, and chemical processes that result in loss of the productive potential of natural resources in areas that remain classified as forest. This distinction explains some of the confusion in estimates of change in forest resources.

Table 1.—Estimates of Closed Forest Areas and Deforestation Rates in Tropical Africa, America, and Asia

Country	Closed forest area (1,000 ha)	Percent deforested per year[a]
Tropical Africa:		
Ivory Coast	4,458	6.5
Nigeria	5,950	5.0
Rwanda	120	2.7
Burundi	26	2.7
Benin	47	2.6
Guinea-Bissau	660	2.6
Liberia	2,000	2.3
Guinea	2,050	1.8
Kenya	1,105	1.7
Madagascar	10,300	1.5
Angola	2,900	1.5
Uganda	765	1.3
Zambia	3,010	1.3
Ghana	1,718	1.3
Mozambique	935	1.1
Sierra Leone	740	0.8
Tanzania	1,440	0.7
Togo	304	0.7
Sudan	650	0.6
Chad	500	0.4
Cameroon	17,920	0.4
Ethiopia	4,350	0.2
Somalia	1,540	0.2
Equatorial Guinea	1,295	0.2
Zaire	105,750	0.2
Central African Republic	3,590	0.1
Gabon	20,500	0.1
Congo	21,340	0.1
Zimbabwe	200	[b]
Namibia	[b]	[b]
Botswana	[b]	[b]
Mali	[b]	[b]
Upper Volta	[b]	[b]
Niger	[b]	[b]
Senegal	220	[b]
Malawi	186	[b]
Gambia	65	[b]
Totals	216,634	0.61
Tropical America:		
Paraguay	4,070	4.7
Costa Rica	1,638	4.0
Haiti	48	3.8
El Salvador	141	3.2
Jamaica	67	3.0
Nicaragua	4,496	2.7
Ecuador	14,250	2.4
Honduras	3,797	2.4
Guatemala	4,442	2.0
Colombia	46,400	1.8
Mexico	46,250	1.3
Panama	4,165	0.9
Belize	1,354	0.7
Dominican Republic	629	0.6
Trinidad and Tobago	208	0.4
Peru	69,680	0.4
Brazil	357,480	0.4
Venezuela	31,870	0.4
Bolivia	44,010	0.2
Cuba	1,455	0.1
French Guiana	8,900	[b]
Surinam	14,830	[b]
Guyana	18,475	[b]
Totals	678,655	0.6
Tropical Asia:		
Nepal	1,941	4.3
Sri Lanka	1,659	3.5
Thailand	9,235	2.7
Brunei	323	1.5
Malaysia	20,995	1.2
Laos	8,410	1.2
Philippines	9,510	1.0
Bangladesh	927	0.9
Viet Nam	8,770	0.7
Indonesia	113,895	0.5
Pakistan	2,185	0.3
Burma	31,941	0.3
Kampuchea	7,548	0.3
India	51,841	0.3
Bhutan	2,100	0.1
Papua New Guinea	34,230	0.1
Totals	305,510	0.6

[a]From 1981-85.
[b]No data; in most cases this is where the areas are very small.

SOURCES: Food and Agriculture Organization/United Nations Environment Programme, *Tropical Forest Resources Assessment Project (GEMS): Tropical Africa, Tropical Asia, Tropical America*, 4 vols., Rome, 1981.

are biologically the most complex and diverse. But the tropical conifer forests cover much smaller areas and have been severely degraded by logging and agriculture. Direct impacts on people are greatest in dry regions where degradation of open forests leads to severe shortages of wood for fuel. But the loss of mountain watershed forest may affect even more people by making river flows more erratic.

Each year approximately 11.3 million hectares of the Earth's remaining tropical forests—an area roughly the size of Pennsylvania—are cleared and converted to other uses. Where cleared land is developed for sustainable agriculture, deforestation can be beneficial. But most land being cleared cannot sustain farming or grazing with available technologies, so it is abandoned after a few years. Often, commercially valuable trees do not grow back quickly because of highly weathered soils, harsh climates, and recurring fires. Thus, highly productive but underused forest resources are giving way to low productivity grasslands and deserts.

Deforestation and degradation of tropical lands are not new. Losses of forest resources have been reported as early as 450 B.C. in the African Sahel and 1000 A.D. in South China. For centuries, tropical deforestation has been associated with poverty and with patterns of economic development that result in inequitable access to farmland. People displaced by development in the lowlands often have been the direct agents of deforestation because they have little choice if they are to survive.

The main agents of tropical deforestation and forest resource degradation continue to be subsistence agriculturalists, livestock raisers, fuelwood collectors, and people who set fires to facilitate clearing or gathering activities. Commercial agriculture plays a smaller role in deforestation today than it has in the past, although in some areas (e.g., Central America and Brazil) clearing tropical forests for cattle ranching causes a large part of the forest resource loss. Commercial logging is also an important cause of forest degradation.

Both subsistence and commercial use of forest lands can cause deforestation. Combined, they form particularly pernicious relationships. For example, loggers build roads through undisturbed forests to remove timber. Slash-and-burn cultivators use the roads to gain access to the forests and clear patches for temporary agriculture. Ranching or commercial agriculture may follow the farmers, exploit the land's remaining productivity, then move on into new areas. These agents of tropical forest change vary in prominence among tropical America, Africa, and Asia.

Alternative techniques exist that could be substituted for these destructive practices. However, sustainable forestry and agriculture practices generally are not being developed and applied. The underlying causes of this failure lie in political, economic, and social forces (e.g., undefined property rights) that cause people to use forests in ways that are inappropriate to ecological conditions. Deterioration of the forest resources seems likely to continue until combinations of improved technologies and enforced resource development policies make sustaining the forests more profitable than destroying them.

TECHNOLOGY ASSESSMENT

This report discusses various technologies to develop tropical forest resources. Some are techniques to manage forests—undisturbed and

disturbed—and some are technologies to use forests to protect related resources such as agriculture and water. Others are techniques to prepare people for the various tasks involved in developing and implementing technologies to sustain the resources.

Technologies for Undisturbed Forests

Undisturbed forests produce many valuable products and services, usually with little or no human management. One way to reduce the rate at which undisturbed forests are converted to other, nonsustainable uses is through systematic preservation of sample ecosystems in parks and protected areas. Another approach is to enhance the value of the forest by developing its resources other than timber—the nonwood products and forest food sources. For either approach to succeed, willing involvement of local people and political commitment from government decisionmakers are essential.

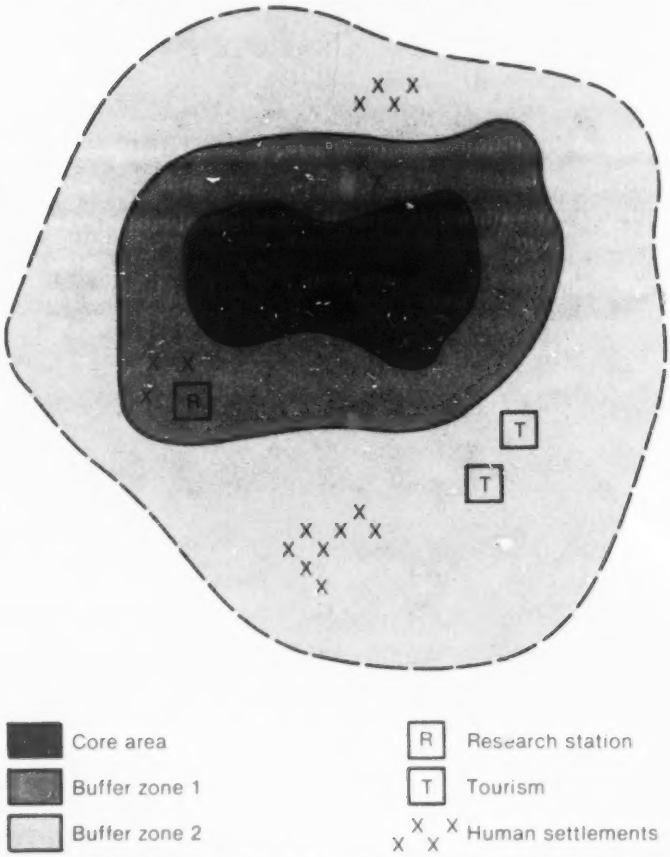
Maintaining Sample Ecosystems.—Parks and protected areas can be managed for direct income (e.g., tourism) and for indirect benefits, such as preventing siltation of reservoirs. Some of these benefits can be estimated for resource allocation decisions. Other major benefits provided by protected areas—e.g., preservation of biological diversity—cannot be measured in dollars. Thus, in the past, the locations of protected areas have been determined more for watershed protection or tourist potential than consideration of biological diversity.

A marked disparity exists in the worldwide distribution of parks and protected areas, with some types of ecosystems well represented and others not represe. .ed at all. Many legally protected areas lack firm commitments from local, national, and international agencies. Consequently, they receive little actual protection or are inadequately managed.

Strict preservation with total exclusion of economic activity is not practical for many sites where protection of undisturbed forests is important. Recognizing the growing demands to develop rural land, protected area planners and managers have begun to pay more attention to socioeconomic and institutional factors. They seek participation from both the people who will affect or be affected by forest resources and the people and agencies that must support management programs.

Some innovative plans that include the surrounding biophysical and socioeconomic setting have been developed for protected areas. One such activity is the UNESCO Man and the Biosphere (MAB) program's worldwide network of biosphere reserves (fig. 3). The management of these reserves considers the needs of local populations and seeks ways to make benefits available to local people. More field experience and monitoring are needed to evaluate the successes of existing biosphere reserves. However, the MAB effort is constrained by a lack of strong, consistent commitments from U.S. and other governments.

Figure 3.—A Typical Biosphere Reserve



The biosphere reserve considers the needs of the local people by incorporating biophysical and socioeconomic factors into its management plan.

SOURCE: M. Batisse, "The Biosphere Reserve: A Tool for Environmental Conservation and Management," *Environmental Conservation*, vol. 9, summer 1982.

Making Undisturbed Forests More Valuable.—Few deliberate attempts have been made to harvest forest products other than timber and fuelwood in a sustainable, organized way. Incentives to maintain unlogged forests would be greater if methods were developed to use forest resources other than timber more fully—either by discovering new, valuable products or by encouraging collection and processing of existing products.

Products obtained from animals and from wood, bark, leaves, or roots of trees and other forest vegetation offer significant opportunities for tropical countries to develop cottage industries. Employment and incomes for people living in or near forests could be improved while encouraging maintenance of the natural ecosystems. Improved assessment of the role of forest products in subsistence economies and develop-

ment of markets for nonwood products could help decisionmakers recognize the value of undisturbed forests. U.S. scientific and managerial expertise could be applied to this problem, especially from the fields of ecology, botany, business, and forest management.

Few technologies exist today that can extract selected renewable resources from a tropical forest while leaving the forest nearly intact. Crocodile and butterfly farming are two examples that are being implemented. The development of other such resource-conserving systems is needed.

Technologies to Reduce Overcutting

Much resource degradation is caused in closed tropical forests by inappropriate wood harvesting methods and in mountain and dry forests by cutting more wood than grows each year. Development of improved wood processing technologies and markets for more of the many tree species and sizes growing in the closed forests would reduce the area that must be logged to satisfy timber demand. Where too much wood is being cut, it may be necessary to reduce demand by increasing the efficiency of woodstoves and charcoal kilns or by substituting alternative energy sources.

Industrial Wood.—Intensive forest harvesting could give increased output per unit area, thus reducing demand to cut elsewhere. But this approach can have both positive and negative impacts. It can make reforestation planting more feasible. On the other hand, it increases the potential for damage to the site from poor road engineering, inadequate site protection, and tardy restoration of forest stands. Intensive harvesting would require strict enforcement of regulations to prevent adverse impacts on the land's long-term productivity.

Intensive harvesting depends on the availability of profitable technologies to extract, process, and market a wider range of tree species and sizes. Grouping species according to their uses (e.g., construction material) is an approach that has been successful in Africa. However, many unused species have sizes, shapes, or wood characteristics that make them difficult to harvest and process and that limit their usefulness.

The use of smaller trees would require costly replacement of existing equipment, which has been designed for large logs. Portable sawmills and small units that could be carried easily and set up to mill logs at the stump could make logging much more efficient. Such technologies might minimize adverse environmental effects from hauling logs but might encourage logging of currently inaccessible areas.

The greatest progress toward making intensive harvest profitable has occurred where multispecies wood chips are produced for wood pulp or fuel. The "press-dry paper process" developed at the U.S. Forest Products Laboratory promises to increase the world market for hardwood chips. However, chipping can have adverse impacts because in

moist tropical forests most of the plant nutrients are located in the trees rather than in the soil. Thus, wood chip harvesting that removes most trees can severely reduce the fertility of the site.

For little known but potentially marketable lumber species, cost-effective preservation and drying technologies are needed to improve use characteristics. Many types of wood are susceptible to attack by termites, other insects, or fungi under tropical conditions. Although wood preservatives are available, they generally are costly. Some less expensive techniques exist but their effectiveness has not been proven.

Fuelwood.—Approximately 80 percent of the estimated 1 billion cubic meters of wood removed anually from tropical forests is used for fuel. The effects of excessive fuelwood cutting are seen first near cities and towns where fuel demand is concentrated. But overcutting does not always remain a local problem. Mangrove forests of Thailand and dry forests of Kenya, for example, are overcut to produce charcoal that is transported by ship to other nations.

Most wood fuel is used in homes for cooking, though tobacco drying and other rural industries also consume substantial quantities. Common domestic stoves waste much of the wood energy, as do traditional methods of making charcoal. Therefore, it should be possible to reduce fuelwood demand and consequent overcutting significantly by disseminating more efficient stoves and charcoal kilns. Attempts to introduce such technologies in tropical nations have had mixed success. Improved stoves are not quickly and widely accepted. Though cheap by U.S. standards, they often cost too much. Some reduce the range of fuels that can be used. Further, improved charcoal production sometimes does not lead to less wood cutting because charcoal makers may use the time or profits they gain to make even more charcoal. Techniques to reduce demand require especially careful planning, monitoring, and evaluation.

Nonwood fuels such as kerosene can sometimes be used to reduce wood demand temporarily while fuelwood plantations are established and while natural forests recover from exploitation. But the costs of obtaining and distributing nonwood fuel substitutes are often prohibitive, especially to the rural poor. Small-scale, renewable energy technologies such as solar dryers have more potential for long-term use, but their adoption is inhibited by financial and managerial constraints.

Substituting plantation-grown wood for natural forest wood clearly is an important option in many tropical regions. Investment in plantations is constrained, however, where access to "free-for-the-taking" forest wood is not restricted. Thus, regulatory controls on fuelwood gathering from the natural forest must be enforced if the fuelwood plantation option is to be used before all the accessible natural forests are destroyed. Where fuelwood has commercial value above the cost of cutting and transportation, the possibility exists that farmers and business will invest in planting trees.

Securing future wood supplies is a social, political, and economic problem. Investments of land, labor, and capital in tree growing are constrained by problems with land ownership, laws, and social organization. Until these are resolved and woodfuel supplies are being effectively replenished, measures to reduce demand will fail to reach the root of the problem. Demand reduction creates no incentives for increased supply; it may achieve the reverse.

Technologies for Disturbed Forests

An estimated 400 million hectares of potentially productive secondary forest* exist in closed tropical forest areas. Approximately 2 billion hectares of tropical lands are in various stages of degradation. Investment in the improvement of secondary forests and reforestation of degraded lands offers opportunities to meet needs for materials, substitute domestic production for imports, and provide new sources of employment in wood production and processing.

Management of Secondary Forests.—Many tropical countries could sustain production of all the wood they will need for decades if adequate investments were made to develop and manage cutover secondary forests. However, such investments are seldom made. Land tenure can be a constraint, but even where the forests are clearly owned and controlled by government forestry agencies or private landowners, investments are usually inadequate. Technologies for sustained forest production exist, but for most of these the time lag before payback begins is too long and return on the investments is too low to attract adequate private and public capital. Opportunities to improve this situation include:

- resolution of land tenure issues,
- public and private investments in research and development to make sustainable secondary forest management more profitable,
- increased technology transfer of profitable resource-sustaining forest management methods, and
- implementation of resource use regulations, tax laws, or subsidies to make investments in secondary forest management more profitable.

Simply reducing logging damage by using appropriate or improved harvesting equipment can increase the number of trees available for a future crop as well as increase natural regeneration and facilitate enrichment planting. But to ensure that this occurs, regulations to control logging practices must be enforced.

Reforestation of Degraded Lands.—Technologies are available to reforest certain degraded lands. But tree planting sometimes does not compete well, in economic terms, with other land uses. The solutions to this dilemma include reducing reforestation costs, reducing planta-

*Secondary forest includes both residual forest that has been cut once or several times during the past 60 to 80 years and second growth forests that invade after periodic cultivation.

tion failure rates by enlisting support of local people, increasing plantation yields, and developing methods to quantify the indirect benefits of reforestation.

Reforestation costs can be reduced if land preparation is used to reduce weed invasion and ensure a favorable environment for seedling growth. Plantation yields can be increased by selecting high-yielding, fast-growing, soil-enriching, and stress-tolerant tree species. Developing and implementing tree breeding and improvement programs can produce varieties with high yields and other desired characteristics. Careful provenance testing—matching the appropriate variety to a particular site—should improve species performance and reduce mortality.

To achieve successful reforestation, several constraints must be overcome:

- shortage of planting stock and lack of quality control in seed and clone production,
- inadequate knowledge of tropical site conditions, and
- lack of information dissemination.

The coordination of collection, certification, and international distribution of high-quality seeds in commercial quantities needs to be improved. Information on proven silvicultural techniques must be disseminated to the local people.

These technical problems can be solved given adequate funding and time. A more subtle problem is to get local people to maintain tree plantations. First of all, they must clearly understand the reasons for planting trees. The trees should produce products local people want, and the people must be convinced that substantial benefits from the trees will accrue directly to them. Often this means using species selected by local people rather than species selected by foresters.

Forestry Technologies to Support Tropical Agriculture

Medium- and long-term maintenance of tropical forest resources may depend more on sustaining the land already under cultivation than on refining use of the remaining forest. Introducing woody perennials into farming and pastoral land (agroforestry) and improving farming techniques for upland watershed areas could help sustain the productivity of lands under cultivation and so reduce the need to clear additional forest lands.

Agroforestry.—Agroforestry encompasses many well-known and long-practiced land-use methods. The aim is to create productive farming systems able to supply a higher and more sustainable output of basic needs and saleable products than occurs without trees. Agroforestry is most important on lands with serious soil fertility problems and lands where inadequate rural infrastructure makes it vital for people to produce most of their own basic needs for fertilizers, food, fodder, fuel, and shelter.

Agroforestry is a newly recognized field and could benefit from a critical examination of practices and quantification of information. Since agroforestry cuts across several disciplines, its research and development requires an interdisciplinary approach. Because of fragmented institutional jurisdiction, however, agroforestry is not receiving adequate support from either forestry or agricultural institutions.

Great technological potential for agroforestry seems to lie in genetic improvement (systematic breeding and selection) of multipurpose tree and shrub species. Selection of appropriate provenances, subspecies, and varieties can greatly enhance the success of agricultural systems designed for particular land requirements.

The potential for farmers and pastoralists actually to adopt agroforestry system improvements is more difficult to assess. Peasant farmers can ill afford the risks of innovation. Large-scale adoption of new agroforestry systems would require creating incentives to enable people to implement new practices in spite of the initial risks and delayed returns.

Watershed Management.—The greatest problems in tropical watersheds occur where subsistence farmers and their livestock move onto steep uplands. Excluding farmers and livestock from such areas can allow vegetation time to recover, but enforcing such policies is difficult. Mechanical structures and replanting methods can restore water flow stability from some deforested slopes. Further, conservation practices exist that allow farming and grazing on many moderate watershed slopes. However, the watershed management techniques are unlikely to become widespread until farmers and herders in upland areas have incentives to stop destructive land-use practices. To provide upland farmers with nondestructive land-use alternatives necessitates:

- developing methods of land use that are more profitable to the local community and at the same time improve control of water flows;
- developing improved techniques to measure and predict tradeoffs of different management actions; and
- testing new technologies and getting the useful ones adopted by the local community. Subsidies from downstream beneficiaries of the watershed protection may be necessary. Sociological studies could help define the type of incentives needed to obtain farmers' cooperation.

Resource Development Planning

Most conversions of tropical forests to other land uses take place without adequate consideration of whether the natural and human resources available can sustain the new land use. Sometimes, destructive forest conversions are an unplanned result of some other, narrowly planned development. For instance, poorly sited logging roads can open highly erodible forest land to unplanned clearing for slash-and-burn agriculture.

This problem can be ameliorated through the use of resource development planning techniques that match land development activities to the natural and human capabilities of specific sites. These techniques can identify which sites can sustain crop production, grazing, reservoirs, new settlements, intensive forestry or agroforestry, and which will be most productive if retained as natural forest.

Ideally, resource development planning includes four components: biophysical assessment, financial (investor's viewpoint) and economic (society's viewpoint) assessment, social assessment, and project monitoring and evaluation. Biophysical assessment is used more often than the others, although it still is underused. Furthermore, the techniques commonly are used to determine the best sites for particular development purposes rather than to develop a comprehensive strategy for all sites in a region.

Use of each of the four planning components is constrained by a lack of information on cause-and-effect relationships. Economic assessment encounters difficulty measuring nonmarket values. Further, the analyses may consider the forest values only of a small site, disregarding the interrelationships between that site and the surrounding area. For example, loss of the genetic resources in a small patch of a large forest may seem unimportant because nearby forested areas contain the same biological diversity. Consequently, individual economic analyses may justify clearing the forested region piece by piece without accounting for the overall genetic loss incurred.

Finally, even well-planned development may prove unsustainable if planning stops after implementation begins. Most planning is done before projects begin when least is known about biophysical and human resources at the site. Continuous planning, monitoring, and evaluation are necessary during and after the project. The major development assistance organizations have begun to institute such procedures but have not yet determined how to use the results.

Opportunities to enhance the use of resource development planning include improving data availability, more demonstration of the techniques' potentials, better communication of planning successes, increasing the number of trained planners, improving techniques for economic and social analysis, and assuring that projects remain open to redirection after implementation begins.

Education, Research, and Technology Transfer

Forest resource development is constrained in most tropical nations by a shortage of professional and technical personnel who know about appropriate technologies and who also understand the institutional, economic, and cultural aspects of forest resource systems. In the near term, expatriates, including U.S. professionals, can provide some expertise. But this is not likely to be sufficient because the scope of tropical forest resource problems is so large and the number of expatriate experts is

few. Further, expatriates lack the political and cultural ties necessary to influence policy. Sustaining tropical forest resources requires development of indigenous expertise in all aspects of resource development. Education, research, and technology transfer are the means to develop expertise both in the United States and in tropical nations.

Education.—U.S. universities can act to sustain tropical forests in two ways: educating professionals who will work in tropical forestry related fields and strengthening tropical nations' universiies. However, tropical forestry is peripheral to the interests of most U.S. forestry schools and the experts are scattered widely among institutions. Consequently, efficient mechanisms must be developed to bring together multidisciplinary teams of researchers and educators and connect them with students, foreign universities, and others seeking to develop tropical forest expertise.

Twinning, which creates associations between tropical nation institutions and individual developed nation institutions, has worked with a few university forestry schools. Consortia of U.S. universities can provide tropical institutions access to a wider range of expertise and experience than twinning arrangements. However, this approach still does not resolve several of the fundamental deficiencies that reduce the effectiveness of U.S. institutions. U.S. forestry schools lack a tropical setting for teaching and research. Further, their curricula do not prepare students to solve the social and institutional problems that confront tropical forest resource development. The development of one or more U.S. centers of excellence in tropical forestry might resolve these deficiencies. For example, a center of excellence in Puerto Rico could focus on Latin American forest development needs, providing the necessary tropical setting as well as benefiting the U.S. tropical forests.

A major objective of U.S. efforts to enhance tropical forest education could be to strengthen schools in the Tropics. Some 138 universities and 220 technical schools in tropical nations provide forestry education and training. Nearly all these schools are new. Most are small and produce few graduates each year. Thus, substantial support is needed to provide in-service faculty training, to produce locally relevant course materials, and to modernize basic education facilities such as herbariums, library collections, and computers.

Resource development professionals, the scientists who develop technologies, and the technicians who implement them are ineffective without strong support from the many people who make decisions about the use of natural resources. Environmental education aims to change people's attitudes and behavior by providing them with the motivation and the knowledge necessary to make decisions and take actions that will sustain natural resource productivity.

Environmental education efforts can be directed at the general public using mass media or programs in primary and secondary schools. Or the efforts can be directed more narrowly at higher level decisionmakers. Unfortunately, the behavioral science basis for environmen-

tal education is not well established, so the techniques must be developed by unscientific trial and error. This development could be accelerated if significant investments were made to evaluate, document, and communicate the environmental education efforts that are under way. Having neither a strong scientific foundation nor substantial documentation of the causes of program success and failure, environmental education projects have a difficult time competing with other projects for funds and personnel.

Research.—Technologies intended to develop renewable resources are likely to fail if they are based on inadequate knowledge. Thus, both fundamental and applied research are necessary components of any strategy to sustain tropical forest resources. Fundamental research is the foundation for applied research, while applied research is needed to improve existing forestry technologies and develop new technologies.

Many experts conclude that sustaining tropical forests is not so much a technical problem as it is an institutional problem. Thus, research is especially needed to determine the interactions between the social and biophysical factors of tropical forest systems. Some knowledge about social and institutional factors is being used in resource development projects supported by U.S. agencies. However, this knowledge usually is based on personal experience, not on careful research. A substantial increase in truly interdisciplinary research could enhance the likelihood that institutional changes would result in sustainable forest resource development.

The techniques used to manage tropical forest resources are generally based on trial-and-error experience gained in past centuries. They have benefited little from the rapid advances in fundamental and applied biology that have occurred recently. **For most tropical forest types, techniques have not been developed that can:**

- produce the products, environmental services, and employment opportunities that local people need, *and*
- sustain the productivity of the resource base, *and*
- be profitable enough to motivate people to risk their scarce capital, labor, and land.

Applied research to improve existing technologies probably will not suffice to meet these goals. Innovations based on new fundamental research will also be necessary.

Low levels and short periods of funding are major constraints on fundamental research in tropical areas, but these are not the only reasons why basic knowledge is inadequate to sustain tropical forests. Most fundamental research in tropical biology has been designed to develop evolutionary theory, and relatively little work has been done or is being done on ecological theory.

Another problem is poor communication among researchers and between researchers and technology users. Most forestry and biology research organizations reward scientists, including those working on

applied research, for publishing in journals that technology users seldom read. In fact, few journals exist that are designed to communicate research results to resource developers. The U.S. Forest Service periodical *The Caribbean Forester* once served this purpose but has been discontinued. As a result of poor communication, the pace of innovation is slower than it needs to be, techniques are reinvented, some mistakes are continually repeated, and potentially successful technologies spread slowly, if at all.

Technology Transfer.—The experience of U.S. forestry organizations shows that many potentially profitable techniques languish for lack of effective technology transfer among scientists, between scientists and technology users, and among technology users. Thus, it is appropriate that international development assistance organizations focus their efforts not on promoting particular technologies but rather on building local institutions' capacities to choose, receive, adapt, and deliver technologies appropriate to local circumstances.

An important constraint on development assistance effectiveness in forestry is the lack of coordination among many bilateral and multilateral projects. Coordination of resource development projects so that each project contributes the appropriate actions at the appropriate time to accomplish long-range plans should be the responsibility of tropical governments. But donor agencies usually fund the projects they identify rather than projects identified in some longer term planning process. One approach to improve planning and coordination of technology transfer is the use of ad hoc international committees that are separate from the policies and problems of individual government agencies or development assistance organizations. Committees such as the newly instituted Coordination for Development in Africa could assist tropical governments in developing long-range plans and in identifying and recommending projects for the various international organizations.

The OTA assessment identified a number of necessary conditions for successful technology transfer.* For most technologies, the lack of these conditions seems to be constraining wider adaptation and adoption:

- Technology is transferred most effectively by direct people-to-people actions. People who are to adapt and apply the technology need to learn it directly from people who have experience applying it.
- The technology needs to be adapted at the users' end to local biophysical and socioeconomic conditions.
- Well-qualified people with knowledge about the technology are needed on the source end of the transfer, and receptive, capable people are needed on the receiving end. These people may be local transfer agents or they may be the end users.

*These conditions were a result of discussions among OTA staff; Roger Moeller, AID; and Gary Eilerts, Appropriate Technology International.

- Another type of actor, the "facilitator," is also necessary. Facilitators understand the technology transfer process, including the market for the technology and its products and the political, social, and economic constraints and opportunities that affect all the other actors.
- Users and transfer agents should be involved in choosing the technologies and in planning and implementing the transfer process so that the technology and the transfer meet actual needs and are appropriate for the local situation.
- All parties involved—source, transfer agents, facilitators, and end users—must feel that they are winners and must, in fact, be winners. Each actor's self interests should be identified at the start of the technology transfer process so that they can be addressed.
- Each participant must be aware of subsequent steps in the transfer process so his or her actions are appropriate to the later steps. This requires early definition of roles for each person involved.
- The environment for technology demonstrations should be similar to the environment that will exist during subsequent steps of the transfer process. Pilot transfer projects should not be unrealistically easy.
- The initial commitment of resources to the process should be sufficient to carry the technology transfer until it is self-supporting.
- The transfer process must include mechanisms through which all participants can contribute effectively to interim evaluations and improvements.

ISSUES AND OPTIONS FOR CONGRESS

Tropical forest resources represent a great opportunity for sustained development because they are fundamentally renewable. However, too little such development is occurring. Instead, the productivity of the forests continues to be diminished. The U.S. Congress has already helped to sustain tropical forests by directing AID and the U.S. representatives to international organizations to give forest resource development higher priority in development assistance programs. To expand this progress, Congress could take actions that would enhance tropical governments' abilities to plan and coordinate resource development projects.

The underlying causes of forest resource deterioration are institutional, social, and economic. Consequently, the reforms needed to support sustainable resource development can only come from the governments and people of the tropical nations. However, the United States can help stimulate such reforms. Some U.S. technologies, such as Landsat imagery, already supply vital information to improve resource development decisions. U.S. diplomacy—for example, supporting the United Nations Environment Program and UNESCO'S MAB program—also can help to foster understanding of resource problems and coordinate international efforts to resolve them.

Congress can address technical constraints more directly. U.S. and international organizations that Congress can influence have the capability to: 1) develop production systems that provide the basic needs of local people while conserving forest productivity, and 2) assist tropical organizations and individuals in developing, adapting, and implementing such technologies. U.S. agencies that are applying this type of expertise include AID, the Forest Service, the National Academy of Sciences, the National Park Service, the Fish and Wildlife Service, and the Soil Conservation Service. Some commercial firms, private voluntary organizations, and U.S. universities also have expertise relevant to sustaining tropical forest resources.

Congress has ways to influence multilateral banks and U.N. agencies, some obvious (e.g., through allocation of funds and assistance) and some subtle (e.g., using the prestige of Congress to give credibility to a new idea). The final chapter describes opportunities for congressional action to:

- expand and coordinate development assistance,
- encourage resource development planning,
- improve tropical forest research and development efforts,
- protect biological diversity, and
- expand U.S. expertise in tropical forest resources.

The U.S. tropical forests are discussed separately in this summary.

Expand and Coordinate Development Assistance

Issue (Projects): Development assistance progress is slow and the gains are insufficient to sustain tropical forest resources. Many opportunities exist to enhance gains already made, but congressional vigilance is necessary to ensure that forestry projects receive an appropriate share of U.S. development assistance funds and that other types of projects complement the forestry efforts.

The Foreign Assistance Act directs development assistance organizations in which the United States participates to give higher priority to protecting against the loss and degradation of tropical forests. Accordingly, AID, the World Bank, the U.N. Food and Agriculture Organization (FAO), and some other multilateral organizations have increased funding in recent years for forest related projects. However, many opportunities for use of development assistance to sustain tropical forest resources are not being pursued adequately. Examples of such opportunities are:

- emphasize agroforestry and innovative crops and techniques that can sustain permanent agriculture on relatively poor soils;
- promote reforestation and management of natural forests to sustain environmental services and produce fuelwood, construction wood, polewood, and nonwood products;
- stress institution-building to enable tropical governments to exercise improved control over timber concession operators; and

- support livestock projects that do not result in deforestation or forest degradation.

Option.—To encourage expanded support for forestry projects, committees of Congress could continue oversight hearings requesting AID officials and U.S. representatives to multilateral development assistance organizations to testify on the extent to which assistance practices accomplish the objectives set forth in section 118 of the Foreign Assistance Act.

Issue (Coordination): Development assistance agencies generally do not coordinate their projects effectively at the country or regional level. To improve their effectiveness, projects could be organized as steps in comprehensive strategies designed to develop sustainable forest resource use systems. Individual development assistance agencies have neither developed nor coordinated such strategies.

The reasons why host governments and international assistance organizations do not coordinate activities more effectively are complex. But coordination could play a key role in improving the cost effectiveness of U.S. assistance. If the Congress decides that improving cost effectiveness is worth relinquishing some degree of U.S. control over what projects are funded, it could mandate increased U.S. effort to enhance the tropical nations' abilities to coordinate the work of development assistance organizations.

Options.—One way to begin such a fundamental shift in the development assistance process would be to direct the Department of State to assess whether various tropical nations are able and politically ready to develop long-term action plans for sustained forest resource development. Another mechanism is to create ad hoc committees of experts from donor nations and tropical nations to work together to identify problems and plan regional forest resource development strategies.

Encourage Resource Development Planning

Issue: Although resource development planning technologies can improve the sustainability of tropical forest development, they are seldom applied to their full potential.

Resource development planning techniques can be used to identify development activities that match the available human and natural resources. The techniques can give decisionmakers a clearer picture of the social, economic, and environmental implications of a particular type of development on a particular site. Also, they can be used to determine the best locations for protection of natural areas to maintain biological diversity while providing tangible benefits. But the application of planning is hampered by shortages of information on how biophysical, social, and economic factors interact.

Options.—To encourage the use of resource development planning, Congress could maintain the availability of low-cost Landsat images to tropical governments. Congress also could direct AID to expand its

Environmental Profiles to include macro-level land classification and collection of information for social and institutional analyses. Further, Congress could direct U.S. representatives to multilateral development banks to promote environmental assessments at an early stage of project planning. This request could be followed up with hearings to determine whether the banks are using environmental assessment procedures effectively.

Improve Tropical Forest Research and Market Development

Issue (Research): Fundamental research, applied research, and technology implementation related to tropical forests are not well coordinated. Moreover, interactions among factors that constrain forest resource development are poorly understood. Consequently, resource development projects often fail and technologies that seem to succeed in trials fail to spread beyond demonstration areas. Research on tropical forest resources needs to be more interdisciplinary and more closely related to technology implementation.

Much work remains to develop profitable technologies that can supply local people's needs while simultaneously sustaining forest productivity. New techniques need to be based on improved understanding of the biological, economic, and cultural factors affecting forest resources. This calls for interdisciplinary research based on an adequate understanding of the needs of technology implementors.

Options.—Initially, Congress could conduct hearings to determine whether the research organizations that receive U.S. funds give adequate priority to interdisciplinary tropical forestry that links research and development. Special attention should be paid to disseminating research results. Congress could increase support for agencies where such research and development is stressed.

The other approaches would be for Congress to appropriate funds specifically to support UNESCO's MAB program or to amend the Foreign Assistance Act to include funds for the United Nations University. Both promote interdisciplinary research. Additionally, Congress could amend the existing legislation that explicitly allocates funds for tropical agriculture to include tropical forestry and agroforestry. Congress also could determine the feasibility of establishing a forestry research program at existing Consultative Group on International Agricultural Research (CGIAR) institutions. Congress could establish a trust fund for the Forestry Department of FAO of the United Nations specifically to support improved communication among researchers and technology implementors.

Issue (Market Development): In many areas sustaining tropical forest resources will depend on markets for local forest products. People seldom attempt to sustain the productivity of natural resources used for subsistence products because these appear to be "free." Govern-

ment agencies typically are not aware of the natural forest's potential to support rural communities.

Tropical forest ecosystems house complex associations of vegetation, wildlife, and other potential resources that could be developed. Development of markets, along with research on ways to manage the unused resources for sustained yields, could help motivate local people and local resource agencies to manage the forests effectively. It could be possible in some places to maintain biological diversity and simultaneously support profitable rural development. However, such market development is likely to reduce economic and even subsistence opportunities for landless poor people.

Options.—Congress could direct and fund the U.S. Forest Products Laboratory to develop new products and market information to use tropical tree species and increase its efforts to transfer technologies. Similarly, AID could be directed to expand its support for synthesis and dissemination of information on underused tropical forest resources and to begin developing markets for those products that can be produced on a sustainable basis.

Protect Biological Diversity

Issue: Benefits from preserving the biological diversity of tropical forests accrue to society as a whole, including future generations in the U.S. and elsewhere, yet the costs are borne by the people of the tropical countries.

Developing new markets and ways of harvesting and using tropical forest species eventually may make it possible to manage natural forests profitably and sustainably. But until the markets and technologies are developed, it is necessary to protect and maintain undisturbed portions of these biologically diverse ecosystems for future generations.

Options.—Congress could take two approaches to help maintain biological diversity. First, it could conduct hearings on its recent amendment to the Foreign Assistance Act which directs AID, in concert with other appropriate agencies, to develop a comprehensive U.S. strategy to maintain biological diversity.

Additionally, Congress could support the creation of an international fund to subsidize the establishment and maintenance of tropical parks and protected areas. Money for such a fund could be contributed by a variety of sources, including transfers from existing assistance agencies (e.g., AID, multilateral development banks, and U.N. agencies), increased export taxes and import duties on tropical forest products, and donations from private foundations and multinational corporations.

Expand U.S. Expertise in Tropical Forest Resources

Issue: U.S. tropical forest resource expertise is widely scattered and is not being developed or used effectively.

The United States has recognized expertise (both individuals and organizations) in many resource fields, including reforestation, watershed management, commercial forestry, resource inventory and mapping, resource development planning, and information collection, processing, and dissemination. But only a few of these experts or organizations have the experience or training to apply their skills directly to the increasingly important field of tropical forest resources.

Options.—Congress could modify the organic legislation of those U.S. agencies whose actions affect the tropical nations or the U.S. tropical territories to state that tropical forests are valuable renewable resources and to direct each agency to conduct its activities without contributing to the unplanned or unmanaged conversion or degradation of tropical forests. Further, Congress could direct Federal agencies to encourage employees to participate in international assistance efforts under existing laws or it could amend legislation to encourage such interchange. Congress could encourage participation of the U.S. private sector to develop and implement technologies to sustain tropical forest resources. Congress could contribute to the United Nations Associate Experts Program whereby young U.S. professionals can gain field experience in tropical forestry. Congress also could designate U.S. centers of excellence in tropical forest resources to develop and make available U.S. expertise in tropical resource issues.

U.S. TROPICAL FORESTS

Introduction

Less than 1 percent of the world's tropical forests fall under U.S. jurisdiction. These forests are located primarily in Puerto Rico, the U.S. Virgin Islands, Hawaii, and the U.S. western Pacific territories of American Samoa and Micronesia (which includes Guam, the Commonwealth of the Northern Mariana Islands, and the Trust Territory of the Pacific Islands). As Congress becomes more involved in efforts to sustain tropical forest resources worldwide, it has reason to pay particular attention to the tropical forests under its care.

Despite their small total land area, the U.S. tropical forests are important resources to local people and economies: they supply food, fodder, fuel, and employment; reduce erosion; and protect ocean fisheries. Most wood products, however, are imported to these areas. For example, Puerto Rico imported $400 million worth of wood products in 1981. Perhaps the most important value of forests on these tropical islands is regulation of water regimes. For instance, because of deforestation the U.S. Virgin Islands no longer has permanent streams. Most other islands also have experienced problems with water quality and quantity.

Only in Hawaii has forestry been made an integral part of the region's economic development. To protect watershed values, most forested land in Hawaii is classified under conservation zoning which restricts or

prohibits conversion to land uses other than forest. Nearly half of Hawaii's designated "commercial forest land" is owned by the State. Since 1962, the Hawaii Department of Land and Natural Resources has followed multiple-use programs for managing water, timber, livestock forage, recreation, and wildlife habitat on these lands. In addition, two of the three programs of the U.S. Forest Service Institute of Pacific Islands Forestry are dedicated to research on Hawaiian forests.

Even though forestry problems still exist in the Hawaiian islands (e.g., the recent dieback of native forests, endangerment of native plants and animals) considerable effort has been applied to understand and mitigate these problems. A number of organizations working to sustain tropical forest resources are based in Hawaii, including the Nitrogen-Fixing Tree Association, the Bioenergy Development Corp., the East/West Center, and the College of Tropical Agriculture and Human Resources at the University of Hawaii. These are among the sources of expertise housed in Hawaii that can be applied to the U.S. tropical territories and to the world's tropical forest resources.

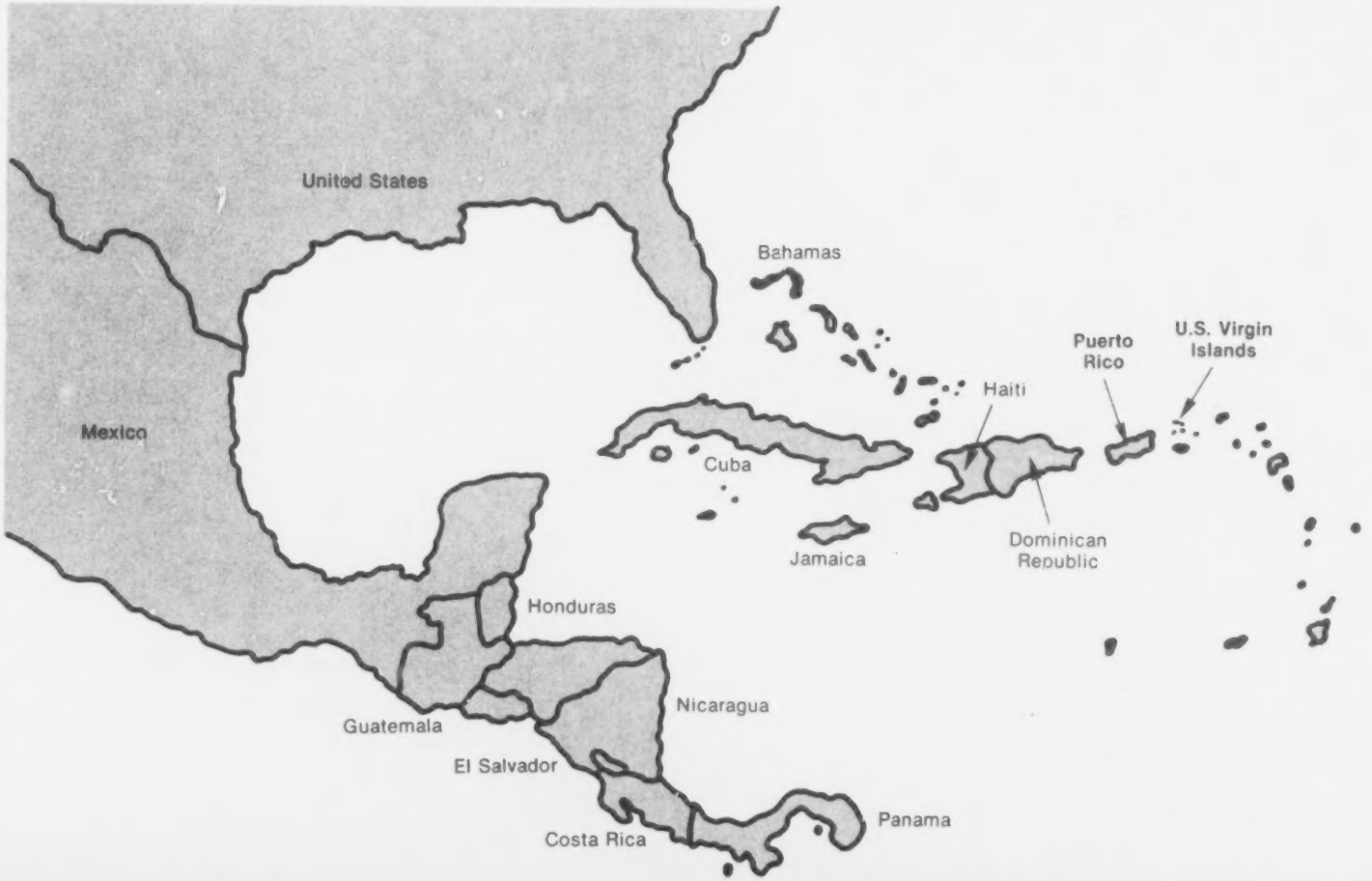
Forest resources in the U.S. Caribbean and Pacific tropical territories are not receiving a similar level of attention. The forests have suffered degradation in the past as a result of poor land use practices. More recently, incentives for local people to undertake and improve agricultural or forestry activities have been reduced by dependence on U.S. Federal income supports and by economic development focusing on industrial growth. This has resulted in a movement away from agriculture and a corresponding increase in abandoned agricultural land and unmanaged secondary forests. In many places, runoff and erosion resulting from past forest loss threaten water supplies and coastal marine resources. With forest resource development technologies, much of the productivity of this degraded and abandoned land could be restored to support economic growth.

Although current overexploitation of forest resources is not a problem in most of the territories, the remaining forests are vulnerable as populations and expectations rise. Future problems could be averted, however, if sustainable forest use techniques could be integrated into strategies for regional economic development.

The U.S. Caribbean Territories: Puerto Rico and the U.S. Virgin Islands

The Commonwealth of Puerto Rico is the largest contiguous tropical area under U.S. jurisdiction (see fig. 4). At least one-third of its land area is under forest cover—mostly second-growth trees, fruit tree plantations, and shade trees in coffee-growing regions. Because Puerto Rico has a relatively large forest area, a relatively well-developed road system, and secure land tenure, it has significant potential for commercial forestry to supply its domestic economy. About 200,000 acres in Puerto Rico have been identified as suitable for commercial forestry. However,

Figure 4.—Location of Puerto Rico and the U.S Virgin Islands



SOURCE: Office of Technology Assessment.

large-scale forestry is hindered by high land prices and a law limiting the acreage that can be owned by an individual or corporation.

Opportunities exist to develop small-scale forest industries to serve domestic markets using technologies that require comparatively low capital outlay, such as the portable sawmills now used in Puerto Rican Commonwealth forests. The sawmills are one component of a Puerto Rico Department of Natural Resources program to bring private landholders into commercial forestry. This program relies heavily on U.S. Federal cost-sharing programs and on funding from the U.S. Forest Service's State and Private Forestry grants. Increased support for these activities could encourage plantation forestry and increase Puerto Rican self-sufficiency in forest products.

The U.S. Virgin Islands have little remaining forest and no forest industry but are used extensively for tourism. Lack of forest management and a growing population in the U.S. Virgin Islands have disturbed local water regimes. Thus, water must be shipped from Puerto Rico or desalinized from sea water at great expense. Reforestation and management of island watersheds could reduce runoff rates, decrease erosion, and enhance aquifer recharge.

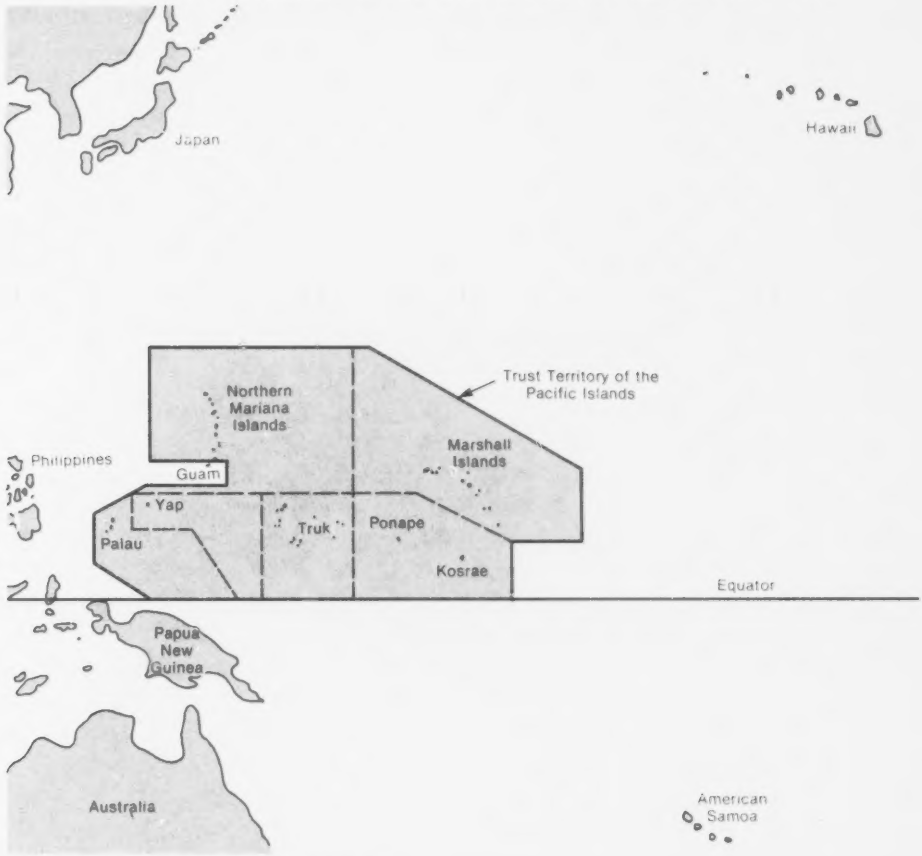
The main constraints to sustaining tropical forest resources in the U.S. Caribbean are lack of support for existing forest resource development institutions and lack of a skilled cadre of local resource managers. The U.S. Forest Service maintains a forestry research station, the Institute of Tropical Forestry (ITF). It also manages the Caribbean National Forest and supports a State and Private Forestry cooperative program with the Puerto Rico Department of Natural Resources and the Virgin Islands Department of Agriculture. At a time when U.S. Forest Service research needs to be expanded to include agroforestry, watershed protection, and other areas of importance to landholders and the public, its research funds and staff size have been reduced.

In the short term, people with general tropical forestry expertise can be attracted to work in the U.S. Caribbean, but in the long term an established method to train people to manage natural resources specific to that region is needed. Increased environmental education, scholarships, and creation of a natural resource management curriculum at the University of Puerto Rico could help train the necessary resource managers. In the meantime, adequate Federal support of Puerto Rico and U.S. Virgin Islands forestry programs through the State Forestry Grants of the State and Private Forestry Division of the U.S. Forest Service are needed to stimulate development, demonstration, and coordination of desirable forestry practices.

The U.S. Western Pacific: Micronesia and American Samoa

U.S. tropical forests exist on some 2,000 islands spread over 3 million square miles in the western Pacific (see fig. 5). Forest cover varies with the nature of each island. Few truly undisturbed forests exist, but con-

Figure 5.—Location of the U.S. Western Pacific Territories



SOURCE: Office of Technology Assessment.

siderable areas of secondary forest have regenerated. Little of this is managed to provide forest products. Fuelwood and some nonwood forest products are harvested for local use, but most wood products are imported.

As in the U.S. Caribbean, the major value of forest resources in the U.S. western Pacific is not timber but regulation of water regimes and protection of biologically rich coastal ecosystems. Island people in this region depend heavily for both subsistence and trade on marine organisms that feed and spawn in mangrove habitats, lagoons, and coral reefs. Unplanned exploitation of upland forests can substantially reduce the productivity of these coastal areas. This already is occurring on some islands.

Transportation costs, limited land areas, and insecure or communal land tenure limit the region's industrial forestry opportunities. However, small-scale management, harvesting, and processing technologies could be applied to the secondary forests and abandoned coconut plantations to increase their provision of food, fuel, employment, and other goods. For example, improved small-scale charcoal production, if de-

veloped and promoted wisely, could increase the importance of wood as a sustainable energy source in the U.S. Pacific. Production from existing agroforestry lands could be enhanced with new techniques. Coconut shell charcoal can be used as a filter in various industrial and pharmaceutical uses and could be exported from these islands.

Any forest development in the U.S. western Pacific territories, however, will require careful planning and management to avoid further degradation of the resources and to ensure the sustainable production of both goods and services provided by the forests. This requires up-to-date and comprehensive data bases on tropical forest resources, their uses, and the potentials for their development. U.S. Federal agencies can play a major role in creating these data bases.

Integrating forestry into development planning in the U.S. western Pacific will require personnel with substantial knowledge in tropical resource management and strong local institutions through which they can work. Yet, no natural resource management education and training programs exist in the U.S. western Pacific territories, and few of the students who receive training at U.S. or other institutions return to work in their own regions. Actions to help supply needed expertise include creating a natural resource management curriculum at the University of Guam and increasing scholarships for potential resource managers. Additional extension services also could be useful. Developing a group of local, grass roots naturalists with generalized training to assist scientists, spread information on appropriate land uses, and help integrate new technologies with local customs could be a joint undertaking of U.S. and local western Pacific organizations.

Issues and Options for Congress

The primary requirement for sustaining tropical forest resources in the U.S. tropical territories is the development of indigenous organizations capable of managing the islands' resources. Because the territories' governments still depend on U.S. support and their natural resource agencies are generally new, small, and undersupported, the U.S. retains a substantial role in both the development of the resource organizations and in the development and implementation of forest-sustaining technologies.

Option: Congress could direct the U.S. Forest Service to expand the scope of research and technology development in its research institutions with jurisdiction in the U.S. tropical territories and increase cooperative efforts with local governments.

Development of forestry management plans, in the short run, will require technical assistance provided by U.S. expertise. Similarly, adaptation of technologies to conditions in the U.S. tropical territories requires Federal assistance. In the long run Federal aid could be replaced when more people are trained in natural resource management at local institutions. Development of programs to encourage private forestry

appropriate for each island probably also will require Federal assistance. The Federal organizations responsible for assisting forestry development in the U.S. tropical territories are too small and their focus is too limited to give the impetus needed for local development. More research, more forestry technology transfer, and greater response to the changing needs of the territories are required.

Option: Congress could support natural resource agencies in U.S. territories by increasing funding for the cooperative State and Private Forestry programs of the U.S. Forest Service institutes in Puerto Rico and Hawaii. Congress could also create a program of grants to territorial governments to encourage investment in privately owned forests.

The Federal Government subsidizes private forestry with cost-sharing and direct payments to forest owners. Replacing these subsidies with a program of grants administered by the territorial governments would provide the flexibility needed to respond to each island territory's unique cultural, economic, and ecological characteristics. Furthermore, it would encourage the development of a constituency concerned with sustaining the forest resources.

NOTE: Copies of the full report "Technologies to Sustain Tropical Forest Resources" can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, GPO stock No. 052-003-00943-9.

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